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Lean manufacturing implementation: bibliometric analysis 2007–2018

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Abstract
In order to preserve competitiveness in their markets, organizations seek incessantly tools to help them manage their activities. To identify scientific production related to lean manufacturing implementation in organizations. This study was undertaken through bibliometric analysis using metadata extracted from two different scientific databases: Web of Science and Scopus, in the period from 2007 to 2018. The literature trend lies in the barriers faced by lean manufacturing implementation, in framework development to support implementation, and in model building to evaluate what has been done. The contribution of this work is in the opportunity to suggest of a knowledge repository to support lean manufacturing projects. The authors' main discussions are related to lean manufacturing models, and the lack of sharing experiences acquired by employees during the deployment process.

Keywords Lean manufacturing implementation · Bibliometrics

1 Introduction

Competitiveness in organizations is currently one of the key factors in ensuring their market survival [1]. This scenario challenges organizations in searching for management models that strengthen their development [2, 3].

One of these models, which has been gaining ground in the industry, is the lean manufacturing [4], marked, mainly, by the search for cost reduction though waste elimination categorized in 7 or 8 different types: overproduction, transport or transference, waiting (time at disposal), defects, over-processing or incorrect processing, excess inventory, unnecessary movement, and non-use of employee creativity [5, 6].

According to Tortorella [7], the lean manufacturing is one approach that stands out in the market as an instrument to increase productivity with quality and financial return. It can be employed in small, medium, and large companies [8] and in any business segment in searching for financial sustainability [9].

Adoption of the lean system requires a profound change in organizational mentality before deployment [10], which for Hino [11] depends on a sound understanding of the Toyota's genes and DNA, without it, the system "is a lifeless drawing of a house."

Organizational culture is one of the factors which can influence lean implementation. Sharing experiences and lessons learned by the team involved in the process are keys to project success [12].

This paper will present a literature review on the current characteristics of lean manufacturing implementations, in an attempt to better understand what has been done in the industry and what are the main trends and opportunities for future research.

Thus, the following question arose: are organizations implementing lean manufacturing tools in their organizational designs? If they are, what is the development of this deployment?

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To answer this question, bibliographic searches were performed in the databases Scopus and Web of Science for the period from 2007 to 2018.

2 Lean manufacturing

The Toyota production system came into being in Japan in the year 1950 at the Toyota plant. The purpose of this system was to increase production using as few resources as possible, decreasing physical effort, use of equipment, time, movement, and space, to add value to the final product.

Until the arrival of lean manufacturing, the most well-known production model was the mass production model. The known practice was the high-volume manufacture of standardized products to meet a large demand [13, 14].

Taj [15] define lean manufacturing as a set of concepts, principles, methods, procedures, and tools to reduce losses in the value stream.

Lean manufacturing is defined by Womack and Jones [16] as the best way to manage an organization with a focus on employees, employees, customers, and suppliers. They also sustain that production must be done with less physical effort, less equipment, less time, and more quantity.

For Shah and Ward [17], lean manufacturing adopts a multi-practice approach to ensure service efficiency through systematic interaction, so that the products are delivered to the customer at the right time without waste.

For Tortorella [18], lean manufacturing is a business model that values the human being as the main human element for continuous sustainability in the organization. The interaction between employees contributes to the knowledge acquisition to support future projects of the organization [19].

Liker [20] points out that the Toyota System's success is based on the combined use of its assembled elements put into everyday practice in a systematic way.

For Liker and Meier [5], the Toyota Production System is based on four points (4P's): (*i*) long-term planning (philosophy), administrative decisions should be made with great care; (*ii*) right process to produce right result (process), create a process flow in which problems can be solved immediately; (*iii*) encourage people (people) to continually improve so that they are proud of their own work; (*iv*) problem solving (problems solution), the organization needs to be able to solve problems and learn to cope if it happens again.

The four sections of the Toyota system are presented in more detail in Fig. 1.

Bhasin [21] says that for a company to implement lean manufacturing, it must find its own way according to its specificities and that this work must be continuous.

For Nguyen [22], leadership, organizational communication, and organizational culture are factors that influence the success of the implementation. Another factor that contributes to the successful implementation of lean manufacturing is the use of all the tools of the system and not just some of them [23].

The main tools for implementation of lean manufacturing seeking some goals are highlighted by Pascal [24], Rother and Shook [25], and Ohno [26]:

- Maximum Availability of Resources
  - TPM (Total Productive Maintenance)–OEE (Overall Equipment Effectiveness)
- Maximum Quality (Zero Defect)
  - TQM (Total Quality Management)
- Minimum Productive Flow/Maximum Speed
  - Cellular Manufacturing, SMED Systems and Error Proof (Poka-Yoke) Systems

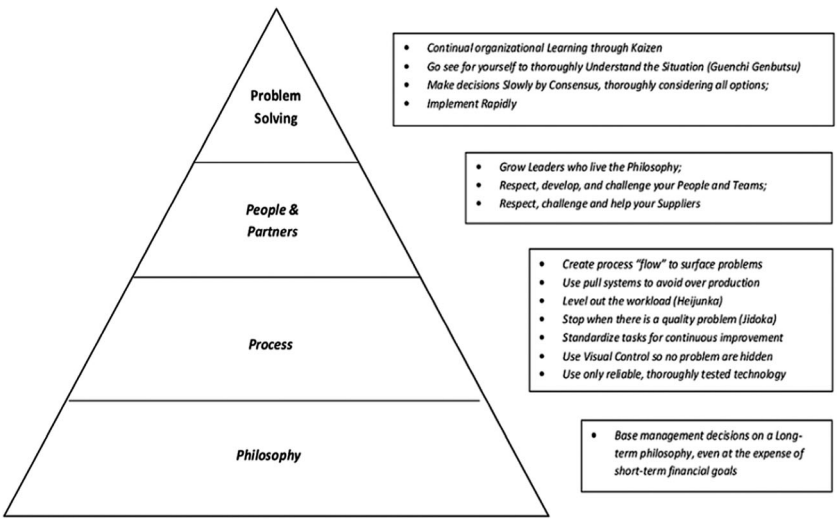

Fig. 1 The 4P's of the Toyota Way—Fonte: Liker [20]

- Minimum Inventory (Zero Inventory)
  - JIT/Kanban Systems

Furthermore, the tools to support decision-making and management:

- VSM—Value Stream Mapping is a tool created to evaluate the company and generate a map of all information flow processes to verify the actual situation of the company;
- Kaizen is a continuous improvement program implemented within the company;
- 5S is intended for organization and cleaning in the workplace
- Visual Management consists of putting in sight all company activities so that all the team involved in the work has access in an easy way.

3 Methodological approach

The objective of this research is to find in the literature articles dealing with lean manufacturing implementation to know the scientific development on this topic.

To carry out a systematic review of the literature, it was necessary to develop the protocol of Table 1.

To achieve the goal of this research, the general data of the articles available in the databases Web of Science and Scopus were considered, in the period from January 2007 to September 2018 regarding to lean manufacturing implementation.

The search was done using the keywords lean manufacturing implementation, which resulted in 104 articles.

4 Results and discussions

In continuity, the selected articles that really dealt with the lean manufacturing implementation out of the 104 articles were preliminarily located; the reading and analysis of the abstracts of these articles was made, selecting 75 articles for detailed analysis.

Figure 2 shows the number of articles per year of publication in this set of 75 articles.

It is observed that in the year 2007, only one article was published, the publication on this theme grows in the year of 2008, it falls again in the year of 2009, returning to grow in the year of 2010, and continues growing until the year of 2014. However, the production of works falls again in the year 2015, then grows and remains stable until the years 2016, 2017, and 2018.

It can be seen in Table 2 that the journal that most published the subject in question was the International Journal of Productivity and Performance Management with 10 (ten) publications, followed by Journal of Manufacturing Technology Management with 7 (seven) publications and by International Journal Of Lean Six Sigma with 5 (five) publications.

Figure 3 show the categories of the 75 (seventy-five) published works regarding to the types of studies and researches.

It is observed that 30 of the localized studies used a case study as a research method. This is because the authors carry out practical studies in companies to verify if they use lean and if they use, how much lean they have. Second is the survey application in organizations, with 16 articles, this is due to the need to verify if the companies of a certain region or segment are implementing lean manufacturing. In the third place, with 15 articles, is the bibliographic research, this was because some authors were interested in reflecting on the subject in question. Fourth is the proposed model, with 14 published articles. This result is due to the authors' concern to build systems to collaborate with the development of organizations.

Figure 4 presents a bibliometric map of cocitation network visualization among researchers who were cited in at least three articles. The cocitation network was generated in the software VOSviewer [27].

It can be observed in the cocitation map that the 15 most recently cited authors are not unanimous among the most productive. This is because the theme in question has been renewed with new researchers.

Among the most cited authors, the highlight on the map goes to Sundar [9], but it is not one of the most productive authors. The author has done a systematic review of the

Table 1 Research protocol for systematic review of the literature

Keywords	*Lean manufacturing implementation*
Data bases	*Web of Science*, *Scopus*
Research areas	*Lean manufacturing implementation*
Exclusion criteria	Articles that did not have the words "lean manufacturing implementation"
Language	English
Document types	Articles
Year of publication	From 2007 to 2018

Source: prepared by the authors

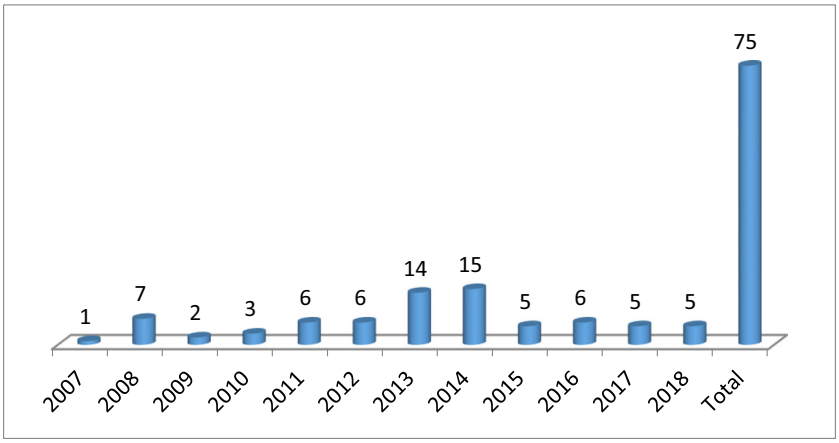

Fig. 2 Number of articles per year of publication. Source: prepared by the authors

literature on barriers and critical success factors during lean manufacturing implementations in small and medium-sized enterprises.

Some of the most productive researchers are among the most cited, namely, Nordin [28]; Karim [29]; Nallusamy [30]; and Tortorella [31]. Among the most productive authors who were not mentioned on the map are Dora [32]; Gupta [33]; Dora, [34]; and Gupta [35].

Table 3 presents the most discussed subjects on the proposed theme.

This paper presents the authors' main discussions regarding lean manufacturing implementations.

The authors argue that the most common barriers to lean implementations are enterprise culture, tool implementation in a fragmented way, the lack of knowledge of the tools by the teams involved in the implementation process, and the need to evaluate the model in the industry that joined the system.

The success in lean implementation depends on the culture change that the organization can achieve in its environment. This kind of change is a challenge for organization because it depends a lot on the willingness of people to change.

Another factor that influences the success of the system deployment is the way organizations are joining the system. Many organizations deploy only some of the system's tools rather than deploying them holistically, integrated, and comprehensively sustainable.

Another barrier that organizations face is the lack of knowledge necessary for the implementation of the system. They are not empowering their employees with courses and training before starting their projects.

There has been much discussion in this literature review of the lack of a standard model for lean manufacturing implementation assessment. The models that exist in the literature to evaluate the organizations that have adhered to the system have failures; for this reason, they can not meet the needs of the organizations [65]. The lack of a standard model for evaluation instigates authors to constantly seek the development of models that will meet this need.

In addition, some articles mention that in general, the adoption of lean is in the beginning and companies are still learning to work on the new production system; for this reason, they are still facing common barriers to the implementation of a new system.

5 Trends and findings

Discussions of lean manufacturing implementations focus on deployment barriers, the standard for implementation, post implementation evaluation, recent adoption of lean manufacturing, and the integration of lean manufacturing with other production systems.

Most discussed topics	Search information	References
Implementation of lean in a fragmented way	Industries are only adopting a few lean manufacturing tools. This practice hinders the success of the adoption of the.	Gurumurthy e Kodali [66]; Fullerton et al. [23]
Post-implementation evaluation of lean manufacturing	Post-implementation evaluation is critical to measuring the organization's performance level.	Malmbrandt and Åhlström [39]; Lucato et al. [67]
Barriers for lean manufacturing implementation	The adoption of a new management model has an impact on the work routine.	Tortorella [68]; Dorota [10]; Cagatay [48]
Integration of lean manufacturing with other production systems.	Integration of management systems improves organizational performance.	Cherrafi [69]; Sanders et al. [70]; Gandhi [71]; Basu et al. [72]
Cutting-edge technologies for lean manufacturing implementations	Leading technologies contribute to the smooth performance of lean implementation.	Sartal e Vázquez [73]; Stork [74]; Ghobakhloo and Azar [75]

Table 2 Lists of the journals published on lean manufacturing implementation

International Journal Of Productivity And Performance Management	10
Journal Of Manufacturing Technology Management	7
International Journal Of Lean Six Sigma	5
Benchmarking: An International Journal	4
International Journal Of Services And Operations Management	3
International Journal For Quality Research	3
Proceedings Of The International Conference On Industrial Engineering And Operations Management	2
International Journal Of Production Research	2
Conferência: International Conference On Advanced Design And Manufacturing Engineering (ADME 2011) Local: Guangzhou, Peoples R China Data: SEP	2
Business Process Management Journal	2
Applied Mechanics And Materials	2
Advanced Materials Research	2
Vision 2020: Innovation Management, Development Sustainability, And Competitive Economic Growth	1
Trends In Food Science & Technology	1
The TQM Journal	1
Supply Chain Management: An International Journal	1
Robotics And Computer-Integrated Manufacturing	1
Production & Manufacturing Research	1
Proceedings Of The 5th International Asia Conference On Industrial Engineering And Management Innovation	1
Procedia Manufacturing	1
Procedia Engineering	1
MATEC Web Of Conferences. EDP Sciences	1
Lean Business Systems And Beyond	1
Journal Of Operations Management	1
Journal Of Manufacturing Systems	1
Journal Of Management Education	1
Journal Of Enterprise Information Management	1
International Symposium On. IEEE	1
International Journal Of Productivity And Quality Management	1
International Journal Of Engineering Research In Africa	1
International Journal Of Business Performance And Supply Chain Modeling	1
International Journal Of Automotive And Mechanical Engineering	1
International Journal Of Advanced Manufacturing Technology	1
International Conference Knowledge-Based Organization	1
Industrial Management & Data Systems	1
Industrial Engineering And Operations Management	1
Industrial Engineering And Engineering Management (IEEM), 2016 IEEE International Conference On	1
Espacios	1
Electrical Engineering And Intelligent Systems	1
Computers In Industry	1
Changes	1
British Food Journal	1
Accounting, Organizations, And Society	1
Total	

Source: prepared by the authors

Gurumurthy and Kodali [66] studied lean implementations, affirming that companies only apply a few tools, making it difficult to successfully adopt.

Fullerton et al. [23] they confirm that lean must be implemented as a whole rather than as an isolated business strategy. The author states that for better performance, it is necessary

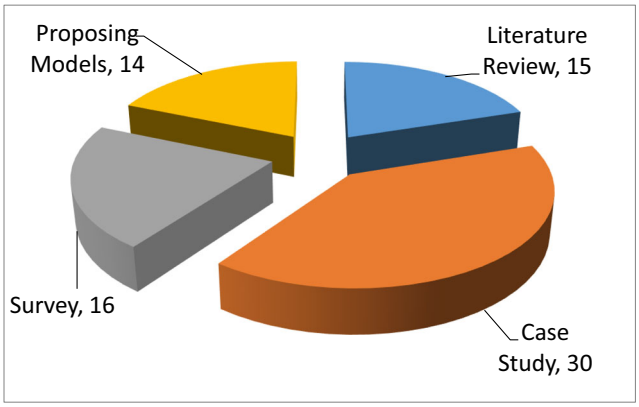

Fig. 3 Categories of the published works. Source: prepared by the authors

for the organization's sectors to partner and work simultaneously in the implementation process.

Dorota [10] conducted a study in Finland to identify the challenges of implementing lean in the country. The author identified that one of the implementation barriers is the lack of lean culture in organizations.

Singh, Garg, and Sharma [76] conducted a study in India to discuss a survival strategy for the industry in recession. They conclude that a strategy to face the crisis in the country is the adoption of lean manufacturing. What happened from then on, Thanki and Thakkar [58], in their studies, assert that the Indian government has adopted lean methodology to increase the competitiveness of Indian industries, specifically manufacturing. Likewise, Paranitharan et al. [77] have confirmed that for India to maintain its competition in the world market, it is necessary that it restructure its manufacturing industries so that they can secure their long-term gains, and the lean system can be the way to do so. Kumar [43] has constructed a framework to verify the relationship between the barriers that affect the implementation of lean manufacturing in Indian industry. As a result, it presented a tool to remove the barriers that affect the implementation.

In this study, it was observed that in general, countries are still beginning to implement lean tools. For this reason, they face many barriers and insecurity in implementation. Malmbrandt and Åhlström [39] developed a tool with 34 items to evaluate the adoption of lean practices.

Lucato et al. [67] proposed a theoretical model to evaluate the degree of implementation of lean in small and medium enterprises. The model was applied in the metropolitan region of São Paulo, Brazil. The results showed that the degree of implementation in large companies is greater in relation to small and medium enterprises.

It was observed in this research that most of the works were dedicated to constructing models for evaluation of lean practices. In the work that includes the own evaluation in the companies that adopted the lean, one notes that the implementations were successful.

Gupta et al. [78] carried out a study on the applications of lean tools through a literature review. The authors identified that organizations did not follow a standard for lean

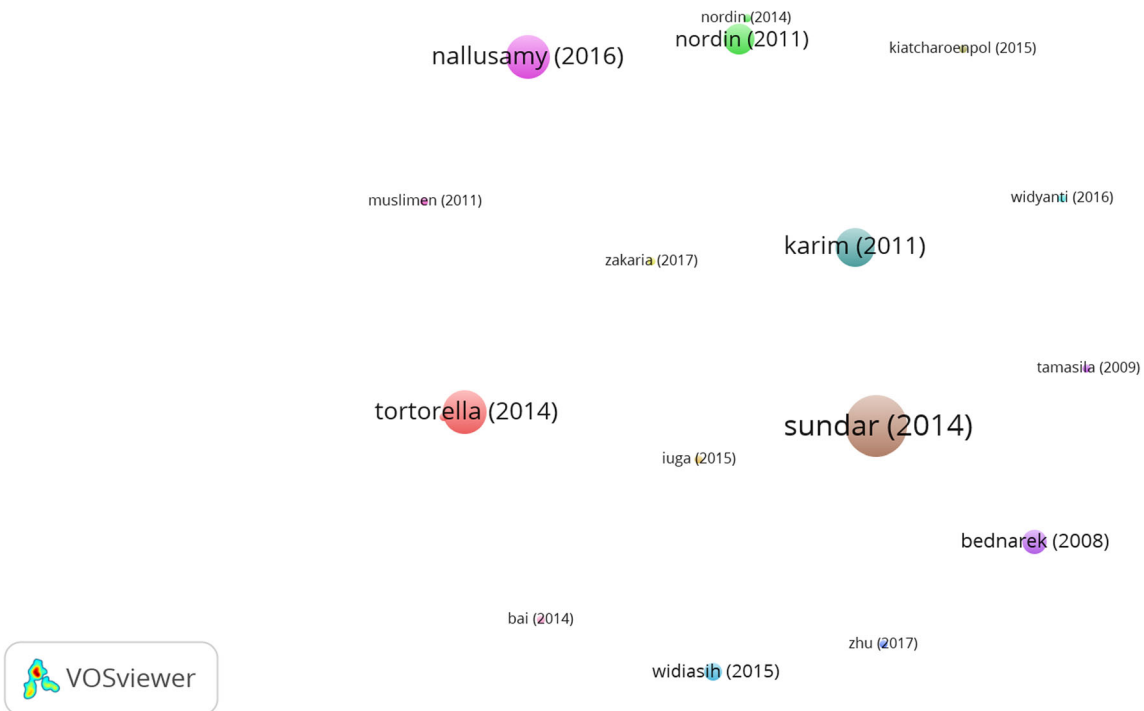

Fig. 4 Bibliometric map of visualization of authors' cocitation network. Source: prepared by the authors using software VOSviewer

Table 3 Subjects groups on lean manufacturing implementation

Topics most covered	Occurrences	Search information	References
Measuring performance	8	Model building to evaluate the results of the implantations in the industry	Bon [36]; Susilawati [4]; Chhabi [37]; Karim [38]; Malmbrandt [39]; Devdas [40]; Yadav [41]; Shannon [42]
Structure to support lean manufacturing deployment	6	Construction of theoretical models to support lean manufacturing application	Kumar [43]; Sundar [9]; Dibia [44]; Gupta [33]; [45]; Nordin et al. [46, 47]
Lean's recent adoption in industry	4	Companies are beginning to apply lean manufacturing tools. For this reason, they face the common barriers to the implementation of a new management model	Cagatay [48]; Dora [32, 34]; Dora (2013); Gupta [35],
Commitment of senior management	3	The implementation of the model requires the support of the administration to make the strategic changes to the adoption of the new model system	Rusev [49]; Fullerton [50]; Herron [51]
Commitment of the working group	5	The success of lean deployments depends on the commitment of the working group	Kumar [43]; Zakaria [52]; Zahraee [53]; Nordin [54]; Doolen [55]
Company culture	10	The change in organizational culture is critical to the success of lean deployments	Nguyen [22]; Shah [56]; Badgujar [57]; Dorota [10]; Thanki [58]; Rose [59]; Wickrama [60]; Nordin et al. [46, 47]; Karim [29]; Bednarek [61]; Näslund [12]
Implementations of the lean model in a fragmented way	3	Industries are adopting just a few lean tools. This practice hinders the success of the adoption of the Lean system	Fullerto [23]; Marodin [62]; Nawanir et al. [63]
Share experiences gained in the deployment process	2	Sharing the lessons learned contributes to the development of future projects of the organization.	Chowdary [64]; Näslund [12],

Source: prepared by the authors

implementation, so they suggest the development of a model, that is, a standard framework for lean services. Karim et al. [38] corroborate this view in the sense that there is a need to develop an effective methodology for the implementation of lean strategies.

Some of the methodologies used in the implementation of lean are the adoption of cutting-edge technologies.

For Sartal and Vázquez [73], introduction of Information Technology in lean implementations can add great value to production planning or maintenance management. For the authors, the activities and processes are constantly being challenged in an unexpected way; for that reason, these activities must be supported by information technologies for a higher performance level.

Ghobakhloo and Azar [75] advanced manufacturing technology and agile manufacturing helps to achieve business excellence. The practical implications of both lean manufacturing and agile manufacturing are information intensive and highly supported by the AMT. The authors state that the automated flow of information between internal processes and the interpretation of operational, tactical, and strategic information improve the performance of organizational activities.

Stork [74] argues that the use of robotics in lean manufacturing is one of the factors that can give greater flexibility, standardization, and optimization in services and processes to achieve lean goals.

Lean manufacturing implementations can also be made in sets with other production systems.

Gandhi et al. [71] carried out a study to identify the factors influencing the implementation of lean and green practices simultaneously. The results show that senior management commitment, technological upgrading, current legislation, green brand image, and future legislation are five important factors for successful implementation.

Cherrafi et al. [69] developed a model to integrate three management systems: Lean Manufacturing, Six Sigma, and Sustainability. The authors relied on the DMAIC improvement cycle in three steps: define and measure, analyze and improve, and control. The proposed model helps the organization identify strengths and opportunities for improvement and assess the breadth and depth of transformation within the organization to achieve economic, environmental, and social performance.

Sanders et al. [70] studied the prospect of lean manufacturing integration with industry 4.0. The authors state that the integration of real-time information and communication systems throughout the plant guarantees minimum generation of waste. Lean manufacturing practices associated with Industry 4.0 technologies and their

simultaneous implementations lead to higher performance improvements [68].

Basu et al. [72] have developed a structural model to serve as a guide to integrate HRM with lean practices. The model includes the attributes required for successful implementation such as Human Resource Management, Integrative Planning and Scheduling, Management Role, Quality Governance, Strategic Process Control, Organizational Goal Satisfaction, and Customer Satisfaction.

It was verified that 43% of the studies carried out an on-site case study to check real situations of the organizations. The research resulted in the need to build models to support lean implementations. This trend confirms the work of Gupta et al. [78] when he suggests in his studies the development of a standard model for lean manufacturing implementations.

It was also observed in this work that the future prospects for lean manufacturing are the integration of this system with other management systems. Simultaneous use with other management systems contributes to the development of organizations.

6 Final considerations

This research has provided an analytical overview of productions on the subject of lean manufacturing implementation. In the period studied, it was possible to observe in the publications that organizations are adhering to lean manufacturing, however, facing the barriers they would face in adopting any new system. To address these barriers, companies are looking for the development of structures to support this deployment.

It was also observed in the research that one of the subjects discussed among the authors is the lack of sharing of the experiences acquired by the employees during the process of implantation of the system. The authors state that the lessons learned from day-to-day work contribute significantly to the development of future projects within the organization.

It was verified in this research that the integration of lean manufacturing with other management systems strengthens the organizational development. For this integration to take place, it is necessary for leading technologies to support lean manufacturing implementations.

Thus, with the development of current technology, information/knowledge recovery has become an essential factor for the realization of decision-making and management processes. Information/knowledge has to be precise and its treatment, storage, and, above all, access has become a determining factor in the competitive world of organizations.

In this sense, the main contribution of this work is in the finding of what seems to be lacking in the literature, the development of a model to store the lessons learned in the day-to-day work during the implementations of lean manufacturing, its principles and tools.

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